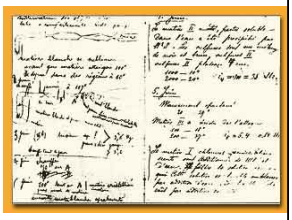
Nuclear Reactions and Energy

Chapter 18

History

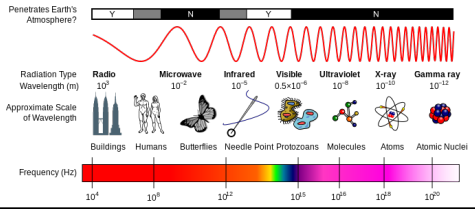
- Henri Becquerel
  - 1896
  - left uranium salt in a drawer with a photographic plate
  - when he developed the plate, he found an outline of the clumps of the uranium salt
  - he hypothesized that the uranium salt emitted some sort of energy
- Marie and Pierre Curie
  - students of Becquerel
  - 2 years later, they discovered Po and Ra while studying uranium ore "pitch blende"

Marie Curie's notebook is still radioactive today!



They discovered….

- Radiation
  - release of matter and energy from nucleus
- Light energy (electromagnetic spectrum)
  - all forms of radiation



Strong Forces

- Protons are held together by strong forces
  - short range force
  - as the distance increases, the force weakens
  - causes protons and neutrons to be attracted to each other

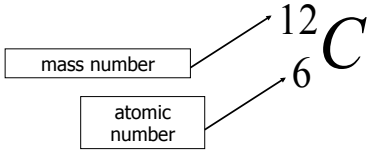
- when the strong force is not large enough to hold a nucleus together tightly, the nucleus can decay and give off matter and energy
- stable nucleus
  - stays together permanently
- unstable nuclei
  - radioactive!!!!
  - nucleus does not stay together; emits matter and energy

- radioactivity
  - the process of nuclear decay
- elements after #83 are radioactive
- all elements after #92 are synthetic and decay soon after they are created

REMEMBER!!

- Mass number = # protons + # neutrons
- Atomic number = # of protons

Example



Isotopes

- most elements have at least one radioactive isotope
- isotope
  - same element with a different number of neutrons
- Example: Carbon-12 (stable)
  Carbon-14 (unstable)

Section 18.2: Nuclear Decay

- **Transmutation**
  - the process of changing one element into another through nuclear decay
- **Radioactive decay**
  - occurs until a stable nucleus is formed

Alpha decay

- alpha decay (α)
  - releases alpha particle (a helium nucleus)
  - a helium nucleus consists of 2 protons and 2 neutrons
  - atomic mass is 4
  - atomic number is 2

  $^{4}_{2}He$

Ex: $^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He$

Beta Decay

- Beta Decay (β)
  - release beta particle it occurs when a neutron breaks down into 1 electron and 1 proton
- the result is an atom with 1 more proton
- Ex: $^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e$

Alpha and Beta Decay

$^{214}_{84}Po \rightarrow {}^{210}_{82}Pb + \_\_\_\_\_$

$^{222}_{86}Rn \rightarrow \_\_\_\_\_ + {}^{4}_{2}He$

$^{214}_{82}Pb \rightarrow \_\_\_\_\_ + {}^{0}_{-1}e$

$^{234}_{92}U \rightarrow {}^{234}_{93}Np + \_\_\_\_\_$

Writing Alpha Decay Equations

- during alpha decay, an alpha particle is released
- the mass number goes down by 4 and the atomic number goes down by 2
- one of the products is always $^{4}_{2}He$

Write alpha decay equations for the following nuclides.

$^{234}_{90}Th$

$^{144}_{60}Nd$

$^{146}_{62}Sm$

$^{151}_{67}Ho$

$^{192}_{78}Pt$

Writing Beta Decay Equations

- during beta decay……
  - a neutron breaks down and changes into a proton and emits an electron $^{0}_{-1}e$
  - the atomic number goes UP by one and the mass number stays the same

Write beta decay equations for the following nuclides.

$^{6}_{2}He$

$^{24}_{11}Na$

$^{201}_{79}Au$

$^{52}_{26}Fe$

$^{42}_{19}K$

Gamma Decay

- Gamma decay (γ)
  - energy release in the form of gamma rays
  - it is a high frequency electromagnetic wave
  - no mass, no charge
  - travel at the speed of light
- alpha and beta decay are particles, where gamma decay is an electromagnetic wave

Decay Series for $^{238}_{92}U \rightarrow \alpha\beta\beta\alpha\alpha\alpha\alpha\beta\beta\ \alpha\beta\beta\alpha$

$$^{238}_{92}U \xrightarrow{\alpha} {}^{234}_{90}Th \xrightarrow{\beta} {}^{234}_{91}Pa \xrightarrow{\beta} {}^{234}_{92}U \xrightarrow{\alpha} {}^{230}_{90}Th \xrightarrow{\alpha}$$

$$^{226}_{88}Ra \xrightarrow{\alpha} {}^{222}_{86}Rn \xrightarrow{\alpha} {}^{218}_{84}Po \xrightarrow{\alpha} {}^{214}_{82}Pb \xrightarrow{\beta} {}^{214}_{83}Bi \xrightarrow{\beta}$$

$$^{214}_{84}Po \xrightarrow{\alpha} {}^{210}_{82}Pb \xrightarrow{\beta} {}^{210}_{83}Bi \xrightarrow{\beta} {}^{210}_{84}Po \xrightarrow{\alpha} {}^{206}_{82}Pb$$

Half-Life

- half-life
  - the amount of time it takes for half the nuclei in a sample of the isotope to decay
- the nucleus left after the isotope decays is called the daughter nucleus
- some half-lives are seconds, others are millions of years

Sample Half-Lives

Isotope	Half-Life
$^{3}_{1}H$	12.3 years
$^{212}_{82}Pb$	10.6 hr
$^{14}_{6}C$	5,730 years
$^{211}_{84}Po$	0.5 s
$^{235}_{92}U$	7.04×10^{8} years
$^{131}_{53}I$	8.04 days

Examples

- If the half life of iodine 131 is 8 days, how much of a 5g sample is left after 32 days?

- How much of a 100 g sample of gold 198 is left after 8.10 days if its half life is 2.7 days?

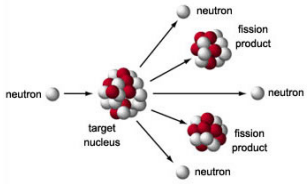
Section 18.3: Detecting Radioactivity

- tools used to detect radiation
  - Cloud chamber
    - used to detect alpha or beta particle radiation
  - Electroscope
    - given a negative charge, its leaves repel each other and spread apart
  - Geiger counter
    - a device that measures the amount of radiation by producing an electric current when it detects a charged particle

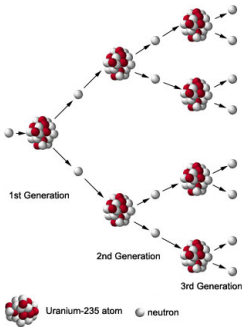
Section 18.4: Nuclear Reactions

- **nuclear fission**
  - process of splitting a nucleus into several smaller nuclei
- **critical mass**
  - the amount of material required so that each fission reaction produces approximately one more fission reaction
- **chain reactions**
  - series of repeated fission reactions caused by the release of neutrons

Fission

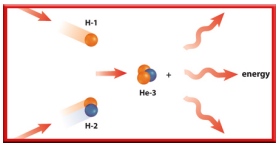


Chain Reaction



Fusion

- **nuclear fusion**
  - two nuclei with low masses are combined to form one nucleus of larger mass



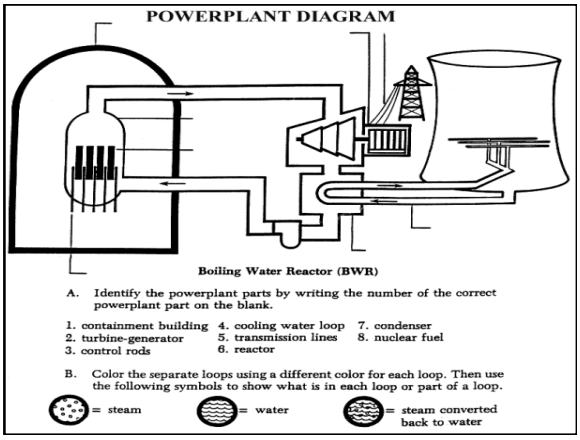
Types of Reactors

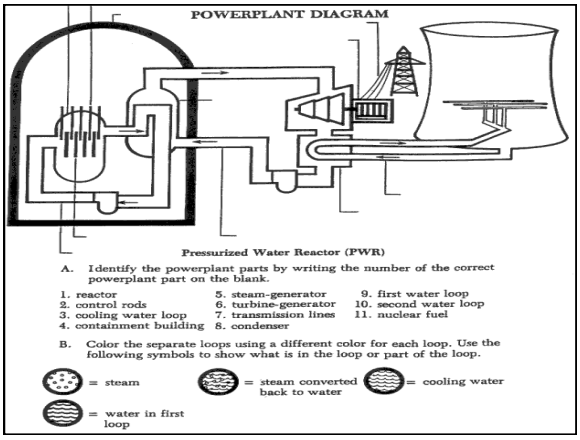
- **Boiling Water Reactor (BWR)**
  - Water boils in reactor vessel
  - Steam to turbine
  - Susquehanna plant and others
- **Pressurized Water Reactor (PWR)**
  - Hot water sent to steam generator first
  - Submarines, Three Mile Island, and others

Nuclear Power Plants
Boiling Water Reactor (BWR)

1. controlled fission reactions release heat energy
2. heat energy is used to boil water
3. boiling water creates steam
4. steam is used to turn the turbines
5. spinning turbines creates electricity

- http://www.pplweb.com/NR/rdonlyres/7C32A442-3C42-4978-9BE4-7128585258E0/0/nuclear.swf
- http://www.pplweb.com/susquehanna+energy+information+center/nuclear+energy+education/fission.htm





Three Mile Island (TMI) Unit 2 (PWR Reactor)

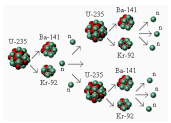
- March 28, 1979
  - most serious accident in the USA
  - A decrease in the cooling fluid due to a valve malfunction in the pressurizer caused a partial meltdown of the reactor core.
  - did not cause any deaths or injury to workers or nearby community members

Chernobyl (RBMK Reactor)

- April 26, 1986
  - Worst accident in nuclear history
  - RBMK (Graphite Moderated Water Cooled)
  - A combination of human error and the loss of water in the core caused the reactor core to melt, a build-up of gases, and an explosion releasing radioactive particulates into the air.

Bombs Away!! Fission or Fusion?

- <u>atomic bomb</u>
  - fission chain reaction emitting 100 million to several hundred million volts of energy
  - a single blow from a neutron to U-235 is all it takes to start the chain reaction
  - Plutonium and Uranium can be used as "fuel" for these reactions



- <u>hydrogen bomb</u>
  - fusion reaction that gets its power from the fusing of nuclei of various hydrogen isotopes into helium nuclei